Taking the Mystery out of Wi-Fi

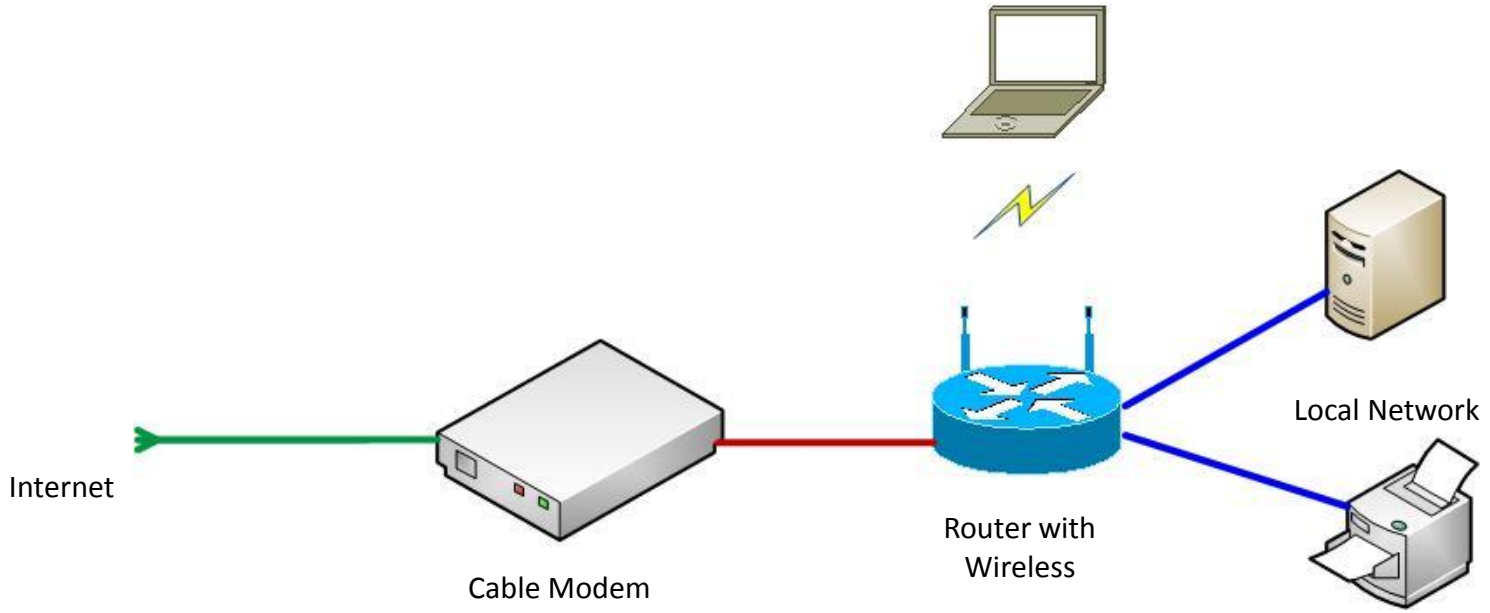
Larry Cooper
Client Technical Architect
larry@LGCdata.com

Topics

- **What is Wi-Fi?**
- Networking basics
- Equipment
- Configurations
- Security
- Tools
- Troubleshooting

What is Wi-Fi?

- Term coined by Interbrand Corporation in 1999
- Wireless extension of a local area network (LAN)



Wi-Fi Standards

IEEE 802.11 Evolution

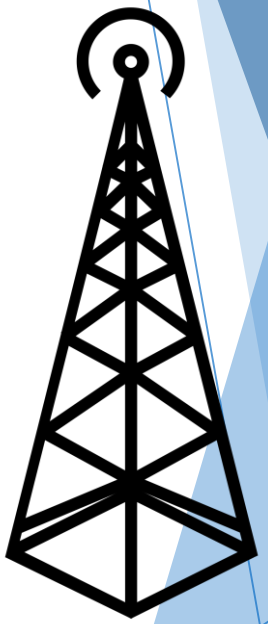
1999	802.11b	2.4 Ghz	11 Mbps	150’
1999	802.11a	5 Ghz	54 Mbps	(few devices manufactured)
2003	802.11g	2.4 Ghz	43 Mbps	150’
2009	802.11n	2.4 & 5 Ghz	300 Mbs*	175’ (uses MIMO)
2012	802.11ac	5 Ghz	>500 Mbs	

*450 or 600 Mbs with 3 antennas

Note: All speeds are theoretical
Speed declines with distance and signal strength

Wi-Fi Distance and Connections

Why not just use a BIG antenna?



- Wi-Fi is bidirectional

  Your phone antenna would need to be the same size!

- Wi-Fi Connection Point name – called SSID
  (Self Service IDentifier)

  Every wireless connection being transmitted has an SSID
  (although it can be configured not to broadcast it!)

Signal Strength

- What is dBm?
  - **dBm** is unit of level used to indicate a ***power ratio*** that is expressed in decibels (dB) with reference to one milliwatt
  - That means the closer the value is to 0, the *stronger the signal*.
  - Logarithmic – A 3 dB change halves (or doubles) the strength
    - 10 dB is a 10x change

- Typical levels

-90 dBm Approaching or drowning in the noise floor. Any functionality is highly unlikely.

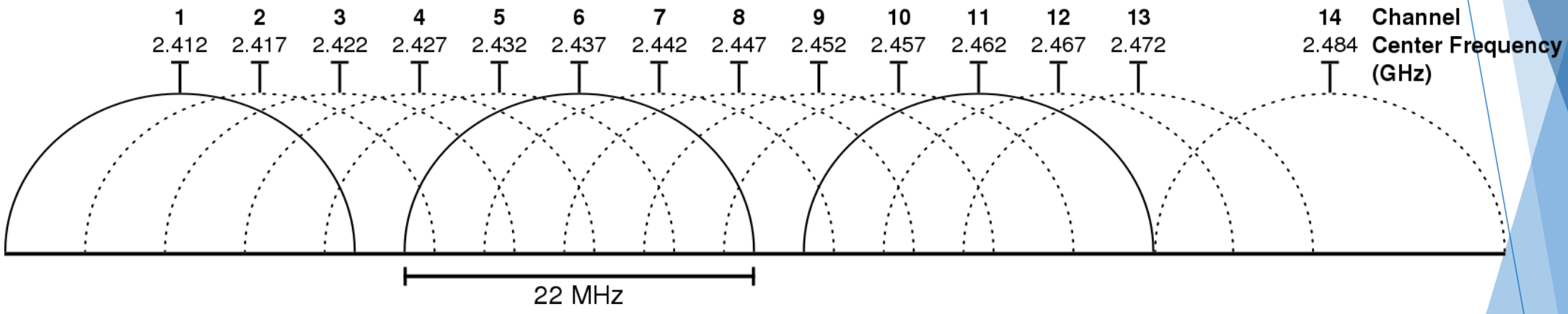
-80 dBm Minimum signal strength for basic connectivity. Packet delivery may be unreliable.

-70 dBm Minimum signal strength for reliable packet delivery.

-67 dBm Very good

-30 dBm Maximum theoretically possible

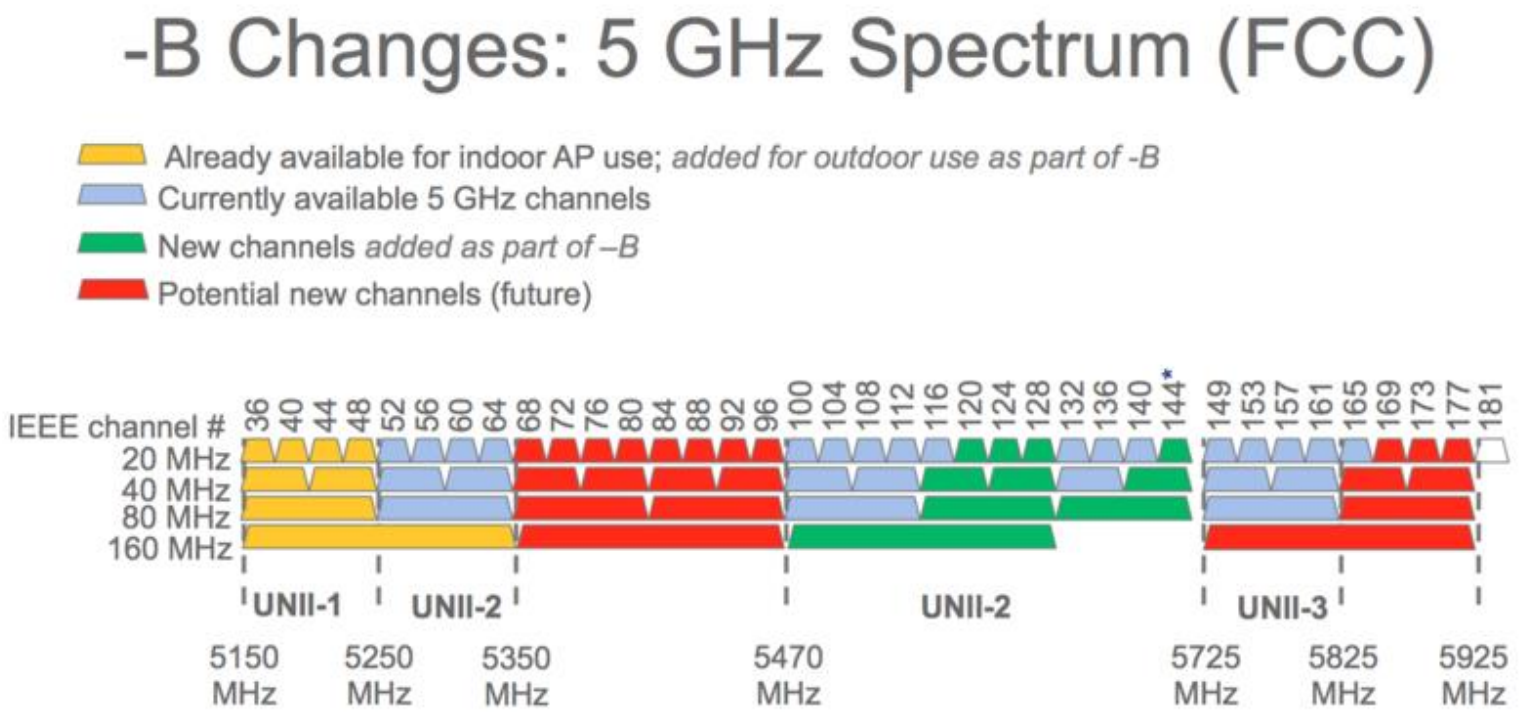
2.4 Ghz Channels and Frequencies



Channels 1, 6 and 11 are the only non-overlapping channels

Illustration by By Michael Gauthier, https://commons.wikimedia.org/w/index.php?curid=8353678

5 Ghz Channels



*Channel 144 was allowed for use prior to the FCC 14-30 order but not supported until –B introduced

Topics

- What is Wi-Fi?
- **Networking basics**
- Equipment
- Configurations
- Security
- Tools
- Troubleshooting

Networking Basics

Speed & Bandwidth

- Maximum data transfer rate

10 Mb	Very old equipment, obsolete
100 Mb	Older equipment, still very common today
1000 Mb	New equipment, highest consumer grade. Also known as “Gig-E”
10 Gb	Very high speed, commercial high speed networking

- MegaBITS (Mb) versus MegaBYTES (MB)

A *BYTE* is 8 *bits*

However, with packet overhead 1 Megabyte equals roughly 10 Megabits

i.e.: 100 Mb connection can theoretically transfer about 10 Megabytes a second*

**Measured speed is dependent upon total network traffic!*

Required Speeds

Common Internet speeds

- 1-4 Mb download, 256 Kb upload DSL
- 20 Mb download, 2 Mb upload Cable modem
- 30 Mb download, 3 Mb upload Turbo mode
- 100 Mb download, 10 Mb upload Fiber & new cable modems

Video streaming requirements

- 3 Mbs – minimum for single video stream
- 5 Mbs – minimum for single HD video stream
- 25 Mbs – needed for ultraHD of 4K video streaming

Network Connections

Network cabling

- Unshielded Twisted Pair (UTP)

  Cat 5 – Used for 10 Mb and 100 Mb speeds

  Cat 5e – Enhanced Cat5 for up to 1000 Mb

  Cat 6 - Used for 1000 Mb and suitable for 10G BaseT
  (each are also available for plenum use)

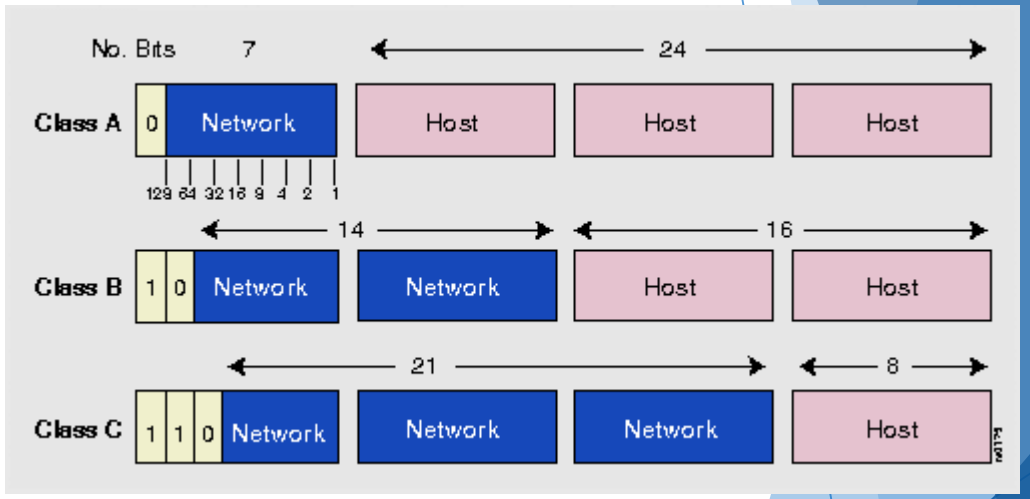
- Coaxial cable
- Fiber Optic cable

  Shortwave and Long wave

Network Addressing & Subnets (IPv4)

- Every device must have an IP Address
- Comprised of three 8 bit sections
- 3 Categories of networks
  - Class A
  - Class B
  - Class C

Address Class	First Octet in Decimal	High-Order Bits
Class A	1 – 126	0
Class B	128 – 191	10
Class C	192 – 223	110



- Private address ranges (“Non-routable”)
  - Class A: 10.0.0.0 - 10.255.255.255
  - Class B: 172.16.0.0 - 172.31.255.255
  - Class C: 192.168.0.0 - 192.168.255.255

Gateway & Ports

Gateway

- Specifies the address of a device to use to access network addresses outside it's subnet.

Ports

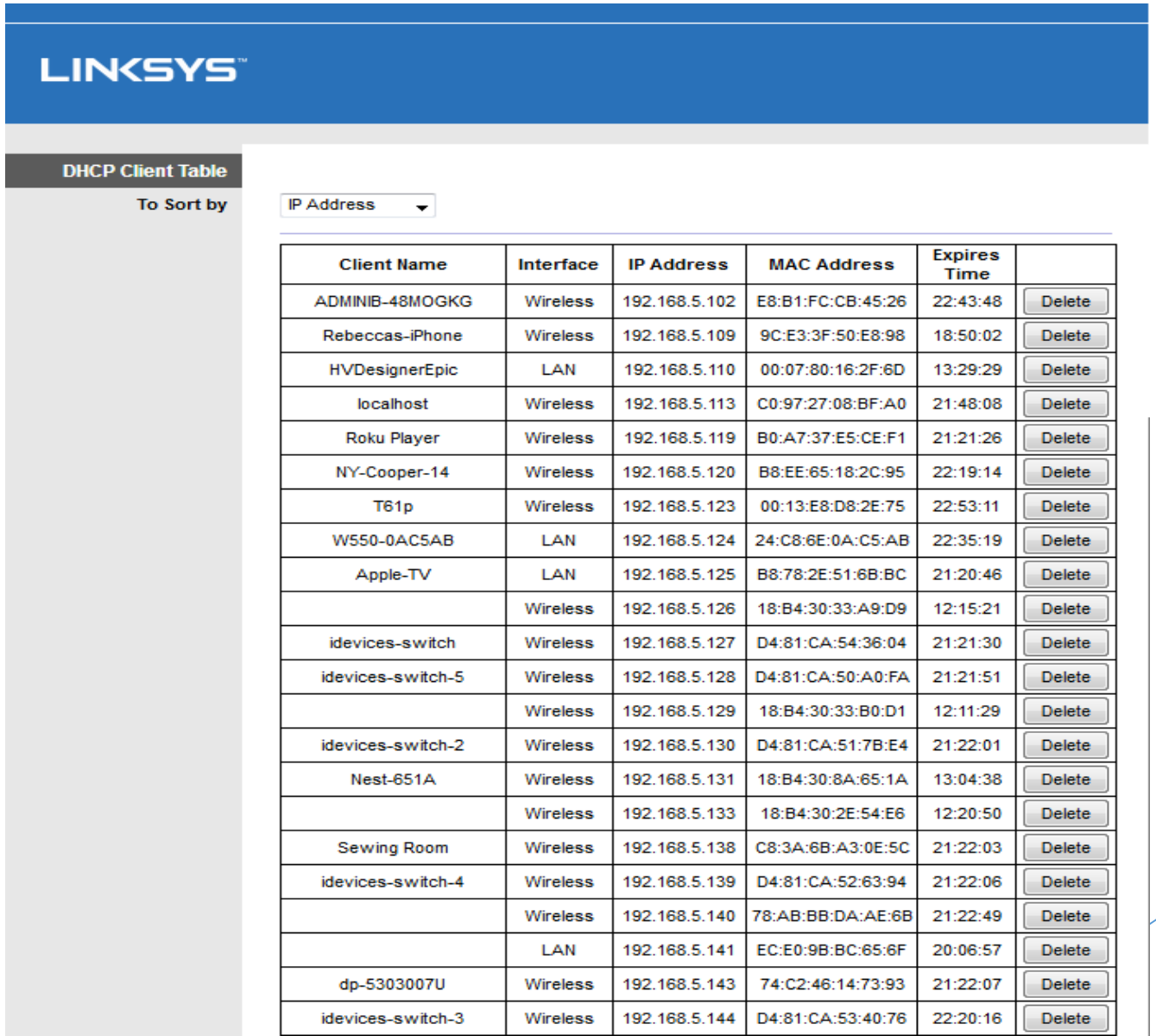
- Specifies what "endpoint" to use at the designated IP address
  - Reserved port examples
    - 80 Http
    - 110 Pop3 (Email retrieve)

Think of the IP address as your street address and the port as which door to use

Assigning Network Addresses

- DHCP (Dynamic Host Control Protocol)
  - Assigned by a DHCP server from a designated pool of addresses
  - Valid for a limited period of time (known as the “lease” time)
    - Lease is automatically renewed if still in use
  - Also assigns subnet, gateway and DNS
  - Assigned network address may be different upon next request
- Static
  - Network address and parameters are permanently set on the attached device
- You don’t want to assign static address in the DHCP pool range!

DHCP Address Table



Client Name	Interface	IP Address	MAC Address	Expires Time	
ADMINIB-48MOGKG	Wireless	192.168.5.102	E8:B1:FC:CB:45:26	22:43:48	Delete
Rebeccas-iPhone	Wireless	192.168.5.109	9C:E3:3F:50:E8:98	18:50:02	Delete
HVDesignerEpic	LAN	192.168.5.110	00:07:80:16:2F:6D	13:29:29	Delete
localhost	Wireless	192.168.5.113	C0:97:27:08:BF:A0	21:48:08	Delete
Roku Player	Wireless	192.168.5.119	B0:A7:37:E5:CE:F1	21:21:26	Delete
NY-Cooper-14	Wireless	192.168.5.120	B8:EE:65:18:2C:95	22:19:14	Delete
T61p	Wireless	192.168.5.123	00:13:E8:D8:2E:75	22:53:11	Delete
W550-0AC5AB	LAN	192.168.5.124	24:C8:6E:0A:C5:AB	22:35:19	Delete
Apple-TV	LAN	192.168.5.125	B8:78:2E:51:6B:BC	21:20:46	Delete
	Wireless	192.168.5.126	18:B4:30:33:A9:D9	12:15:21	Delete
idevices-switch	Wireless	192.168.5.127	D4:81:CA:54:36:04	21:21:30	Delete
idevices-switch-5	Wireless	192.168.5.128	D4:81:CA:50:A0:FA	21:21:51	Delete
	Wireless	192.168.5.129	18:B4:30:33:B0:D1	12:11:29	Delete
idevices-switch-2	Wireless	192.168.5.130	D4:81:CA:51:7B:E4	21:22:01	Delete
Nest-651A	Wireless	192.168.5.131	18:B4:30:8A:65:1A	13:04:38	Delete
	Wireless	192.168.5.133	18:B4:30:2E:54:E6	12:20:50	Delete
Sewing Room	Wireless	192.168.5.138	C8:3A:6B:A3:0E:5C	21:22:03	Delete
idevices-switch-4	Wireless	192.168.5.139	D4:81:CA:52:63:94	21:22:06	Delete
	Wireless	192.168.5.140	78:AB:BB:DA:AE:6B	21:22:49	Delete
	LAN	192.168.5.141	EC:E0:9B:BC:65:6F	20:06:57	Delete
dp-5303007U	Wireless	192.168.5.143	74:C2:46:14:73:93	21:22:07	Delete
idevices-switch-3	Wireless	192.168.5.144	D4:81:CA:53:40:76	22:20:16	Delete

DNS (Domain Name Server)

- Looks up the destination name to find the IP address

- i.e.: nslookup www.pittsfordpres.org

  Server: dns-cac-lb-02.rr.com

  Address: 209.18.47.62

  Non-authoritative answer:

  Name: www.pittsfordpres.org

  Address: 192.135.244.228

VLAN and VPN

VLAN is a Virtual Local Area Network

- This allows many logical networks to exist in a physical network
- Commonly used to isolate network segments

VPN is a Virtual Private Network

- This allows two remote points to be securely connected (typically through the Internet in an encrypted, isolated connection)
- Commonly used for remote access or connecting remote locations

QOS – Quality of Service

- More sophisticated equipment provides priority for designated devices and/or types of data
- When available, typically used to assign VoIP (voice over IP – i.e.:network attached telephones) a higher priority to avoid dropouts

Topics

- What is Wi-Fi?
- Networking basics
- **Equipment**
- Configurations
- Security
- Tools
- Troubleshooting

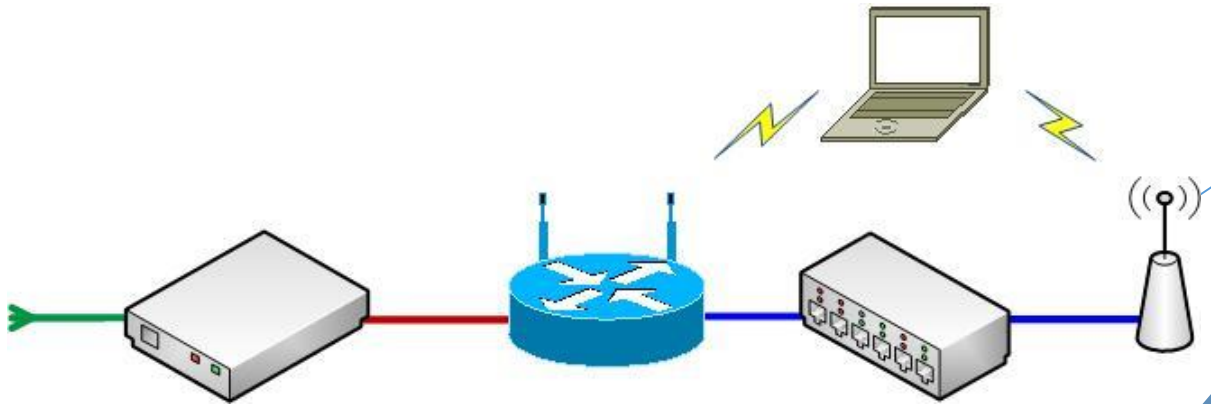
Networking Equipment

Consumer versus Commercial

- Consumer
  - Less costly, but limited in simultaneous connections, management & longevity
- Commercial
  - Data Center network grade - High performance, highly reliable and high cost!
  - Small Business network grade - Reliable equipment at reasonable cost

Network Devices

- Cable modem or Optical Network Termination device (ONT)
- Firewall
- Routers
- Hubs
- Switches (& POE)
- Wireless Access Points (aka WAP)
- Repeaters



Wi-Fi - Wireless Access Points

Different types

- Integrated with router
- Standalone
- Standalone with clustering

Differences

- Frequencies
  - 2.4 Ghz and/or 5 Ghz
- Simultaneous number of users
  - 16, 32, 64
- Number of transmitters/receivers
- Antennas

Repeaters

- Repeaters retransmit the Wi-Fi signal to extend the distance

- Single band repeaters reduce the bandwidth by more than half

  Since the transmit and receive operate on the same channel, it must stop receiving data to retransmit it to the WAP – thereby reducing the throughput.

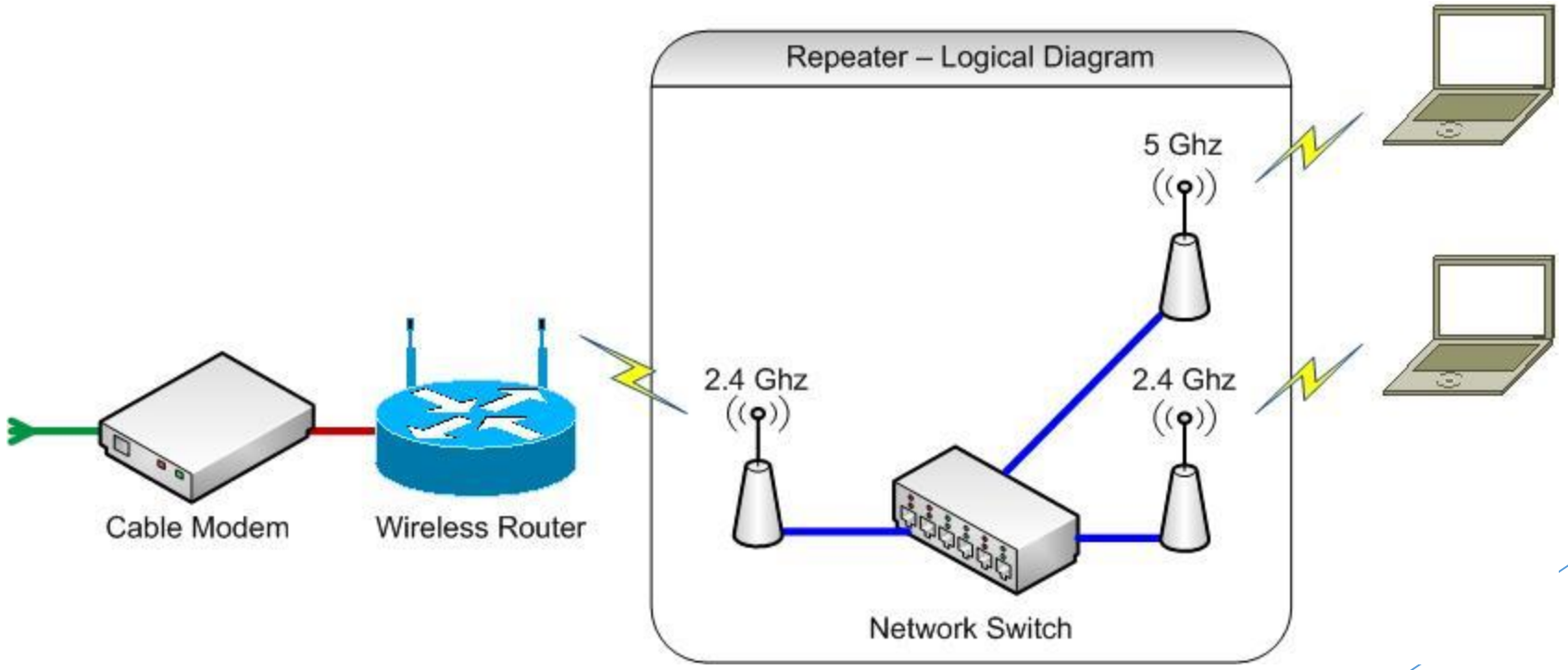
- Repeaters operate best in a multi band mode (if so capable)

  i.e.: Transmit and receive to the end device on one band (5 Ghz) and transmit and receive to the WAP on the other band (2.4 Ghz).

Repeater Configuration

The same radio is typically used for each band.

- This means it cannot be simultaneously transmitting and receiving on the same band



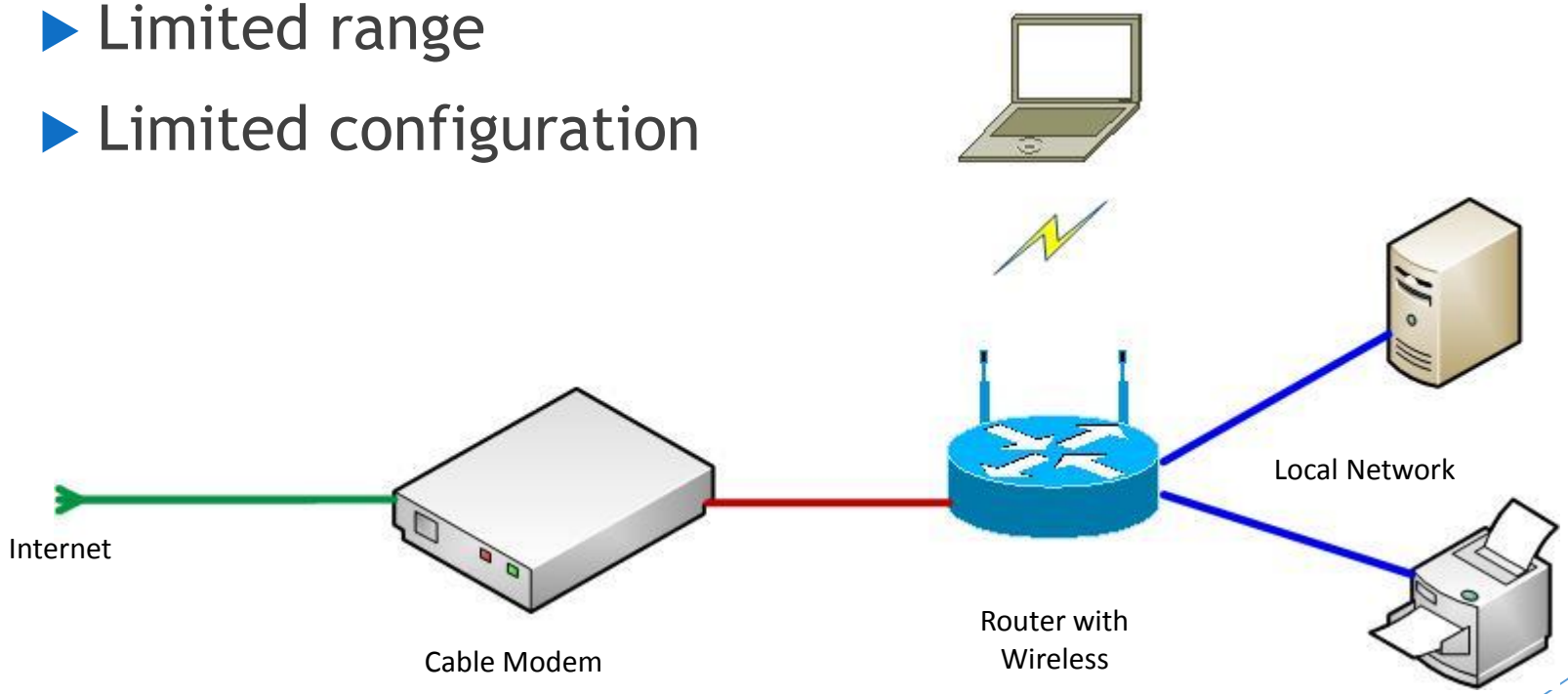
Topics

- What is Wi-Fi?
- Networking basics
- Equipment
- **Configurations**
- Security
- Tools
- Troubleshooting

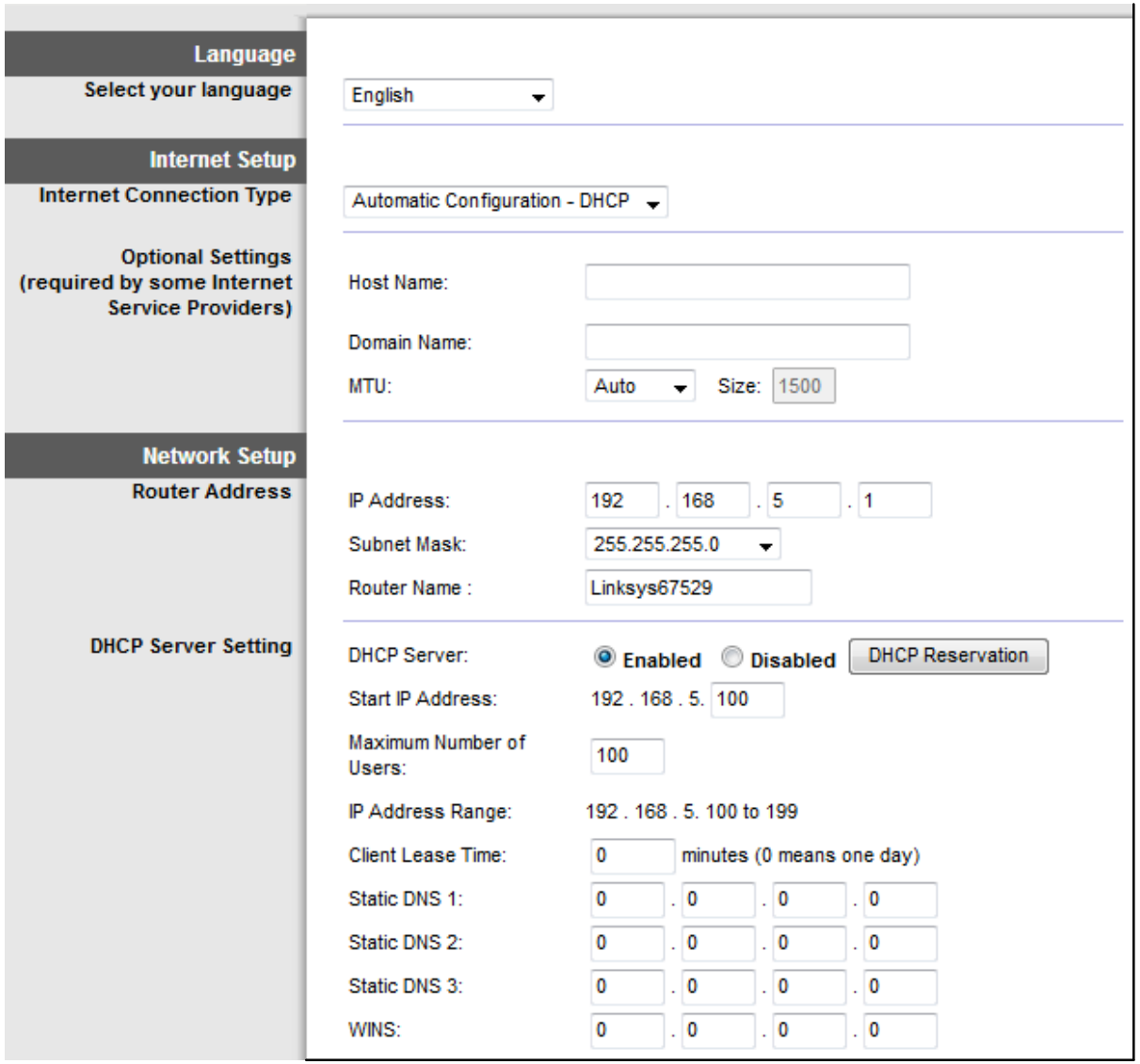
Basic Wi-Fi

Integrated router and Wi-Fi

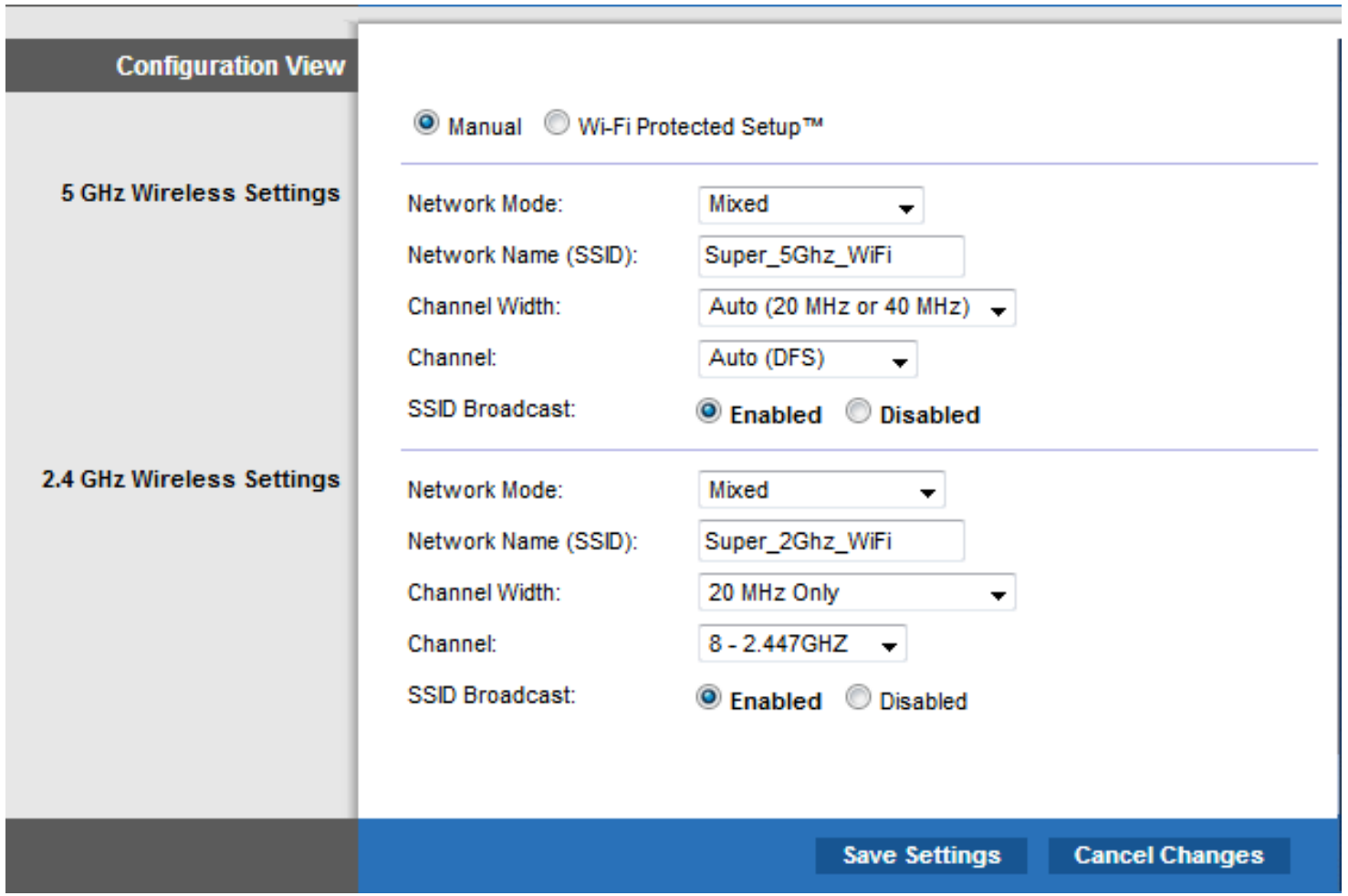
- Inexpensive
- Limited range
- Limited configuration



Setting DHCP address pool



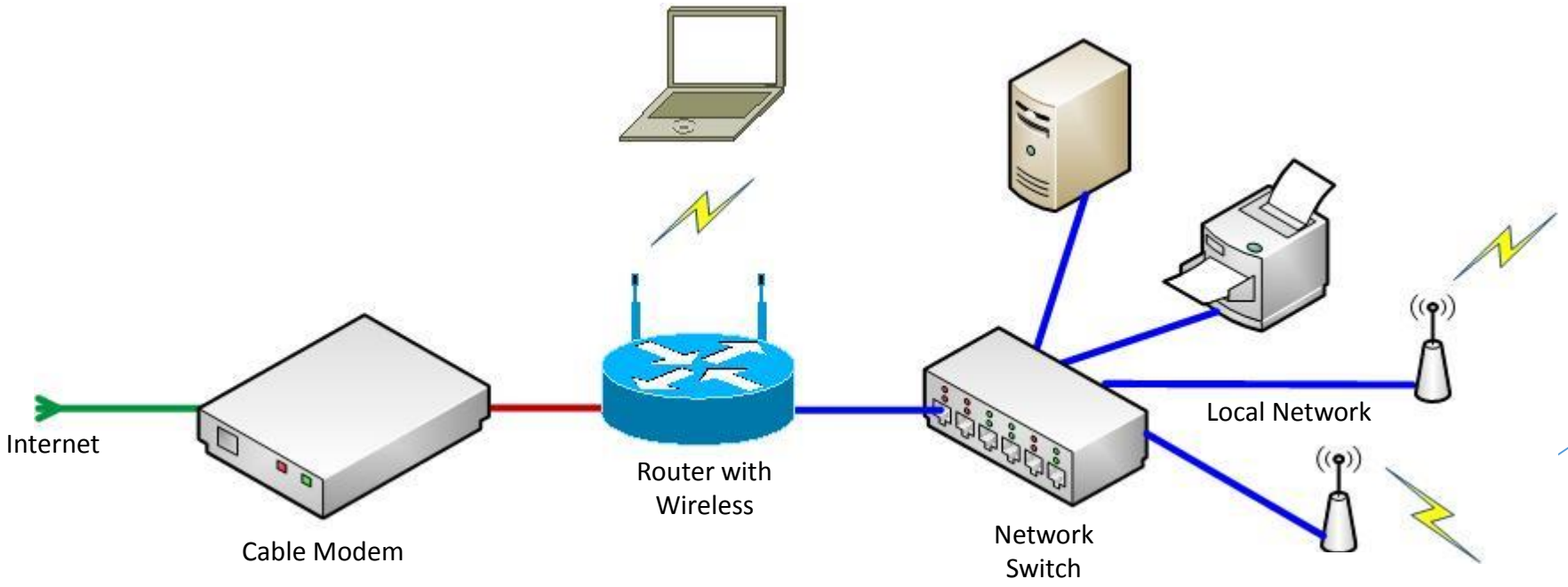
SSID Setup Screen



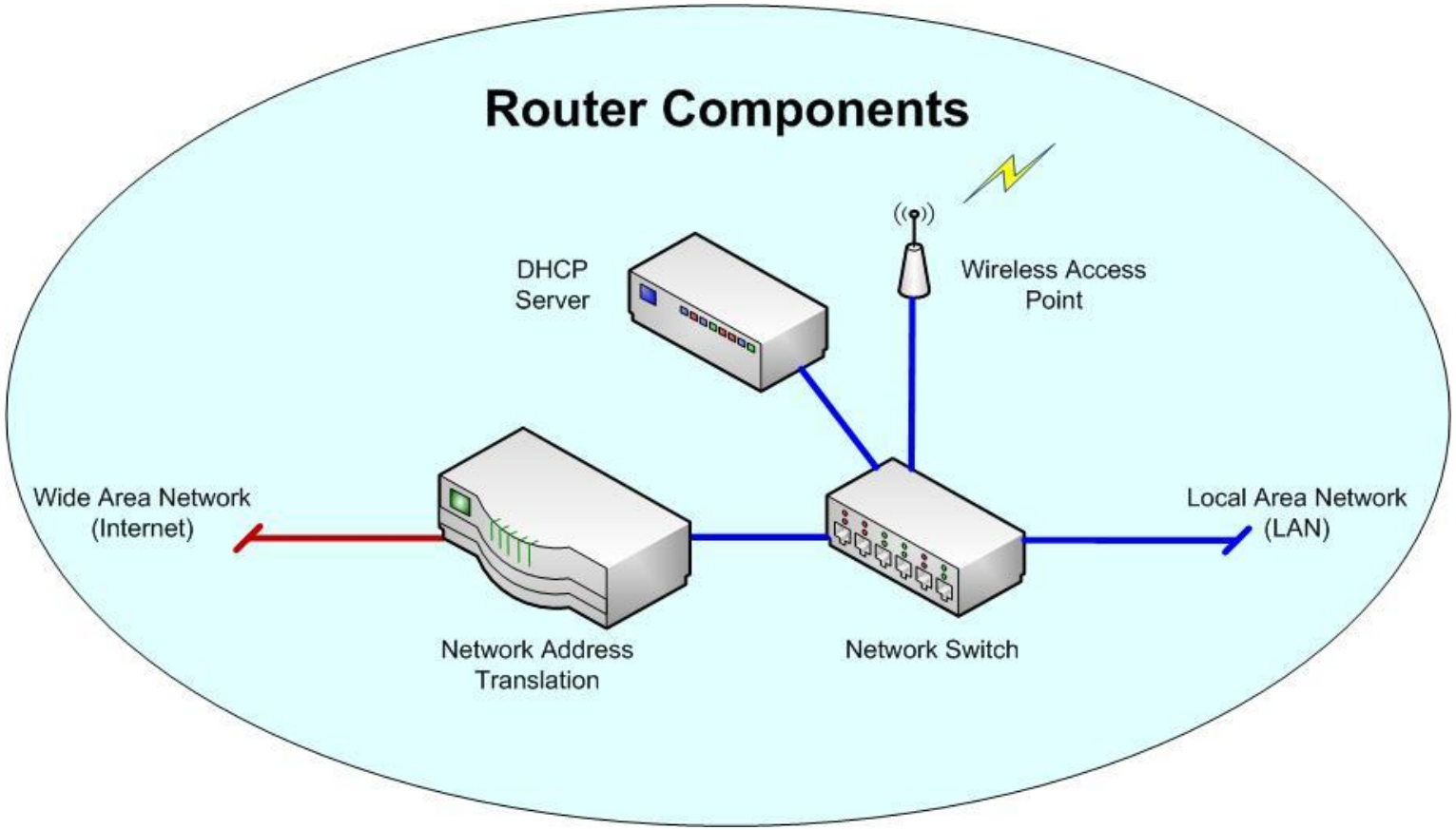
Basic with Additional Access Points

Router and Wireless Access Points

- Router (with or without integrated Wi-Fi)
- One or more Wireless Access Points
- Old routers can also be used as Wireless Access Points
  (DHCP must be disabled on router used as a standalone wireless access point)



Router Internal Components

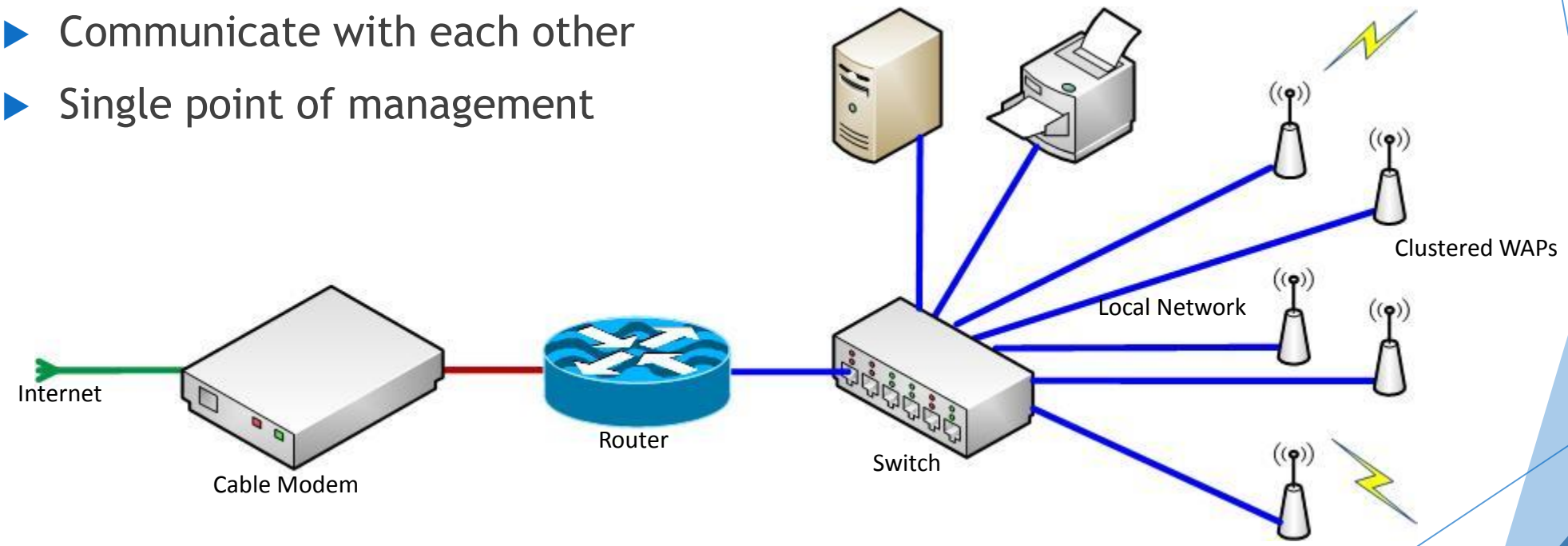


Disable DHCP on a router being used as a standalone wireless access point

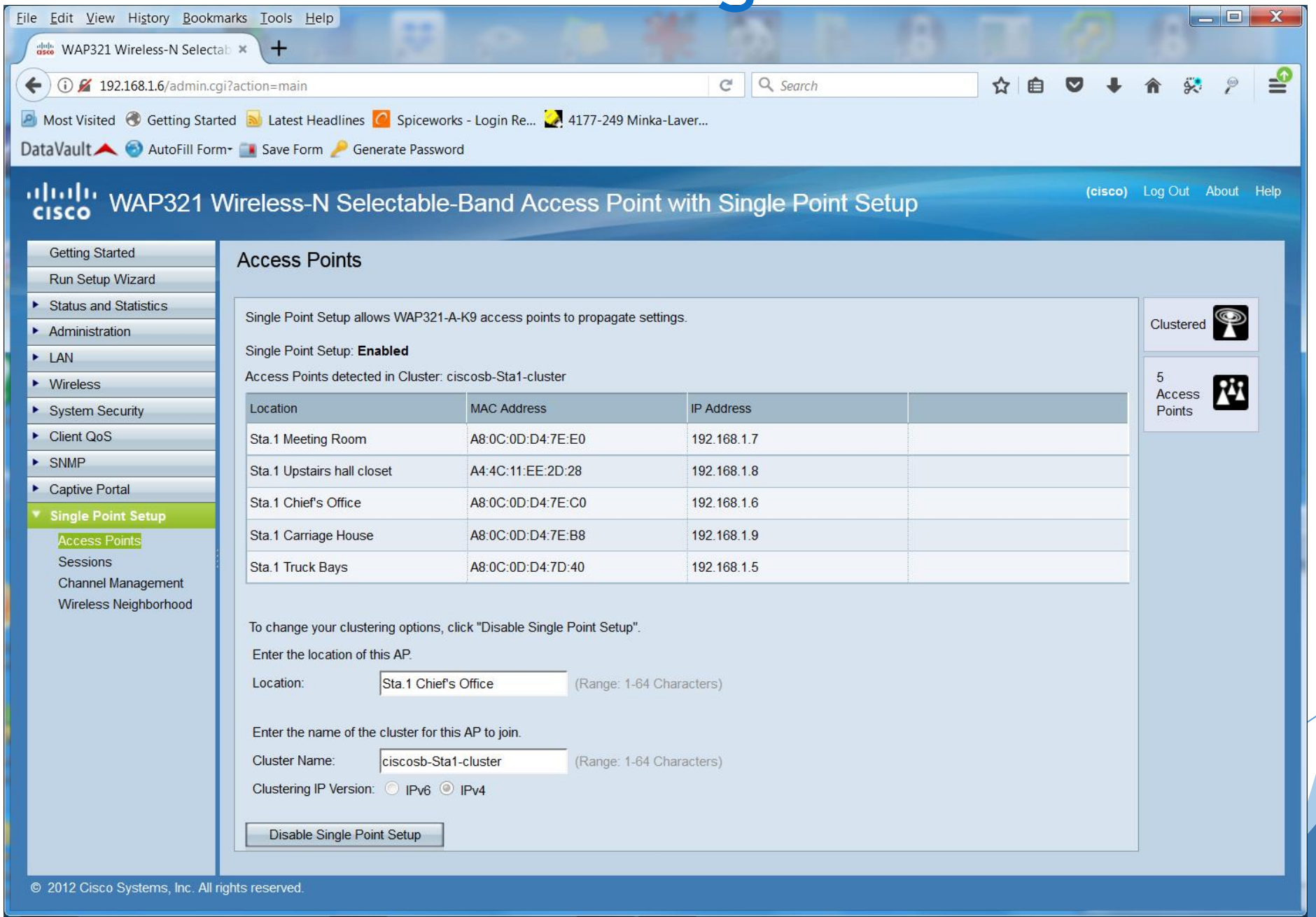
Clustered Wireless Access Points

Router with Clustered Access Points

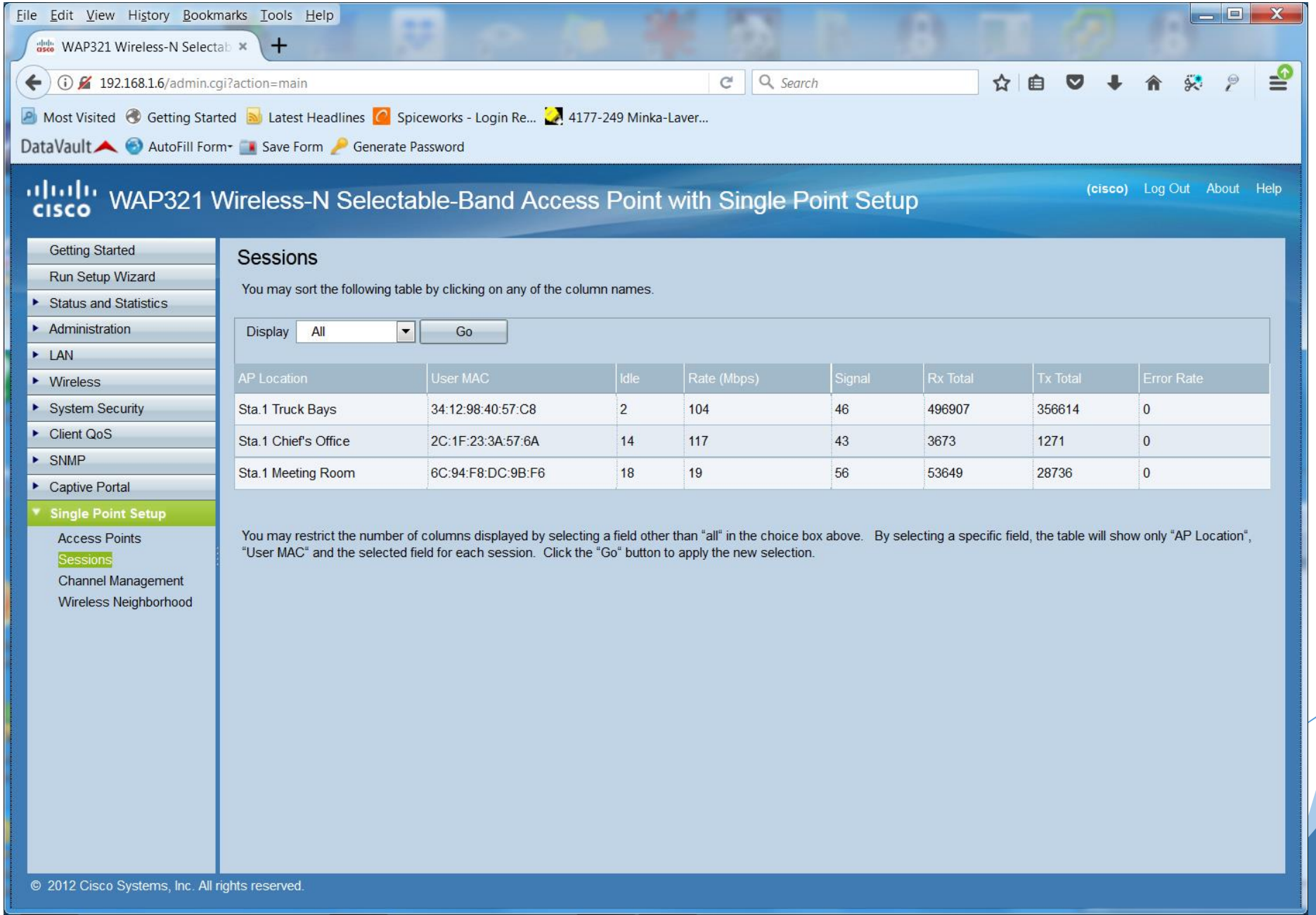
- Multiple WAPs acting together as a cluster
- Share common SSIDs
- Communicate with each other
- Single point of management



Cisco WAP Clustering



WAP Sessions

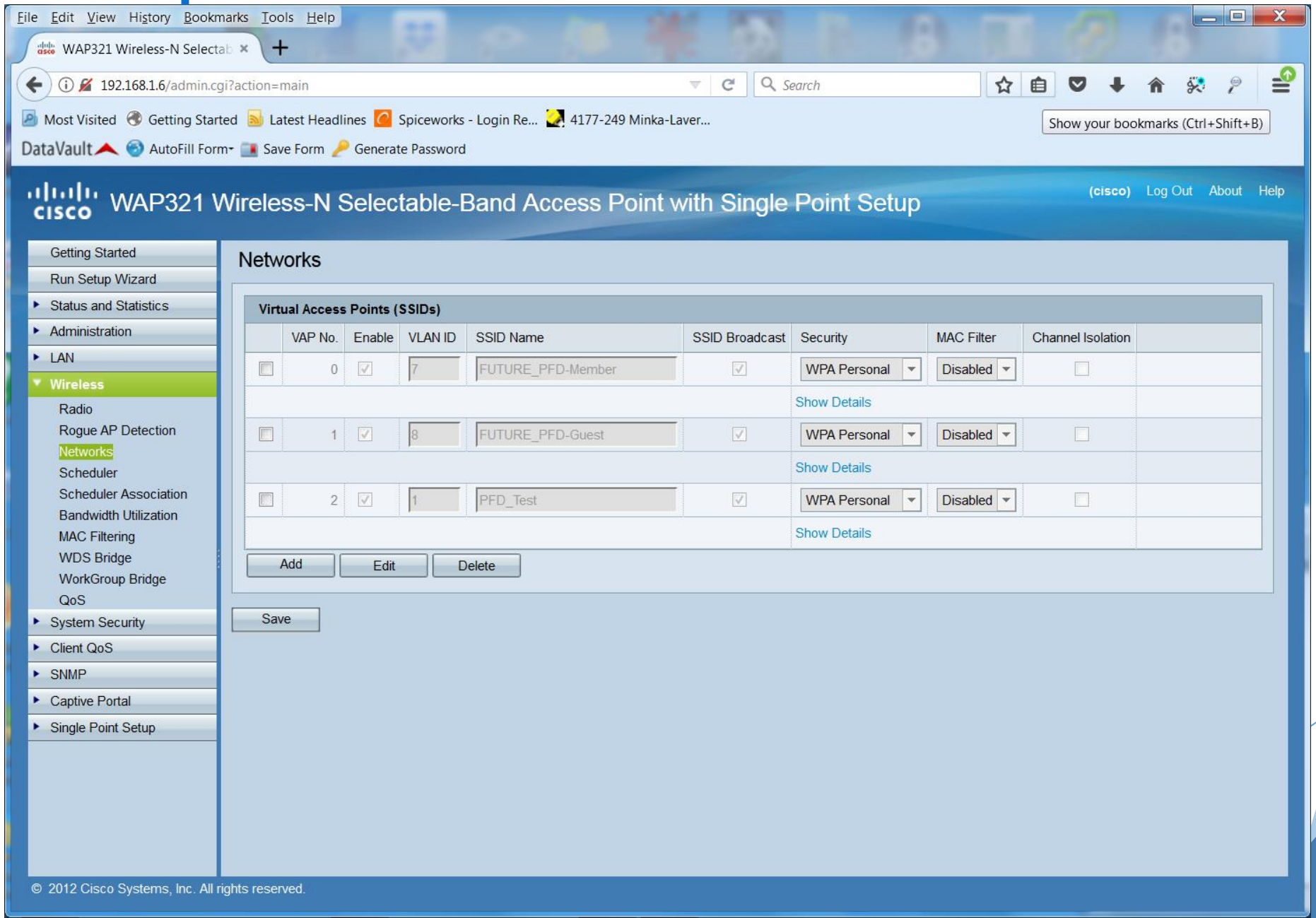


Multiple SSIDs

- Use multiple SSIDs to restrict network access
- Requires WAPs capable of multiple SSIDs and network equipment (router and switches) than support VLANs (802.1Q)

- Example:
  - Wi-Fi connection names (SSID) each with different passwords and access levels
    - PittsfordPres_Admin — Can access Internet and all network devices
    - PittsfordPres_Staff — Can access Internet and network printers
    - PittsfordPres_Member — Can only access the Internet
    - PittsfordPres_Guest — Internet only via manual login

Multiple WI-Fi SSID

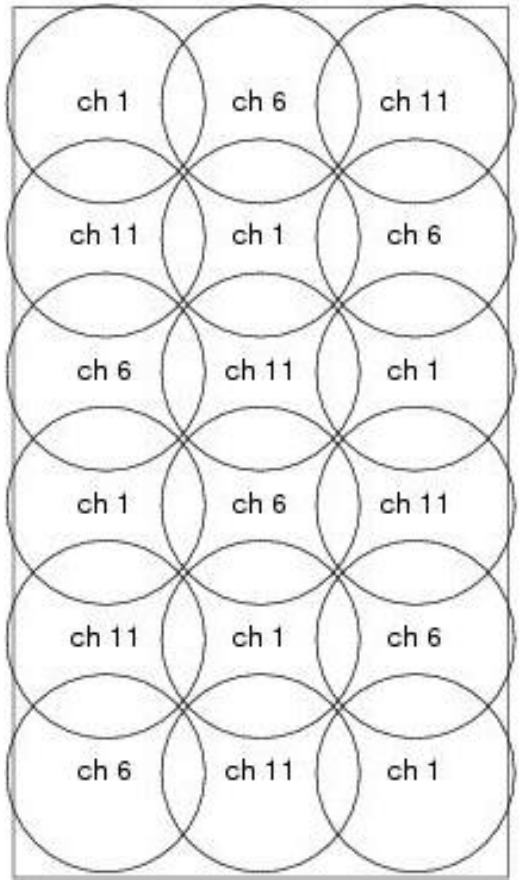


WAP Locations

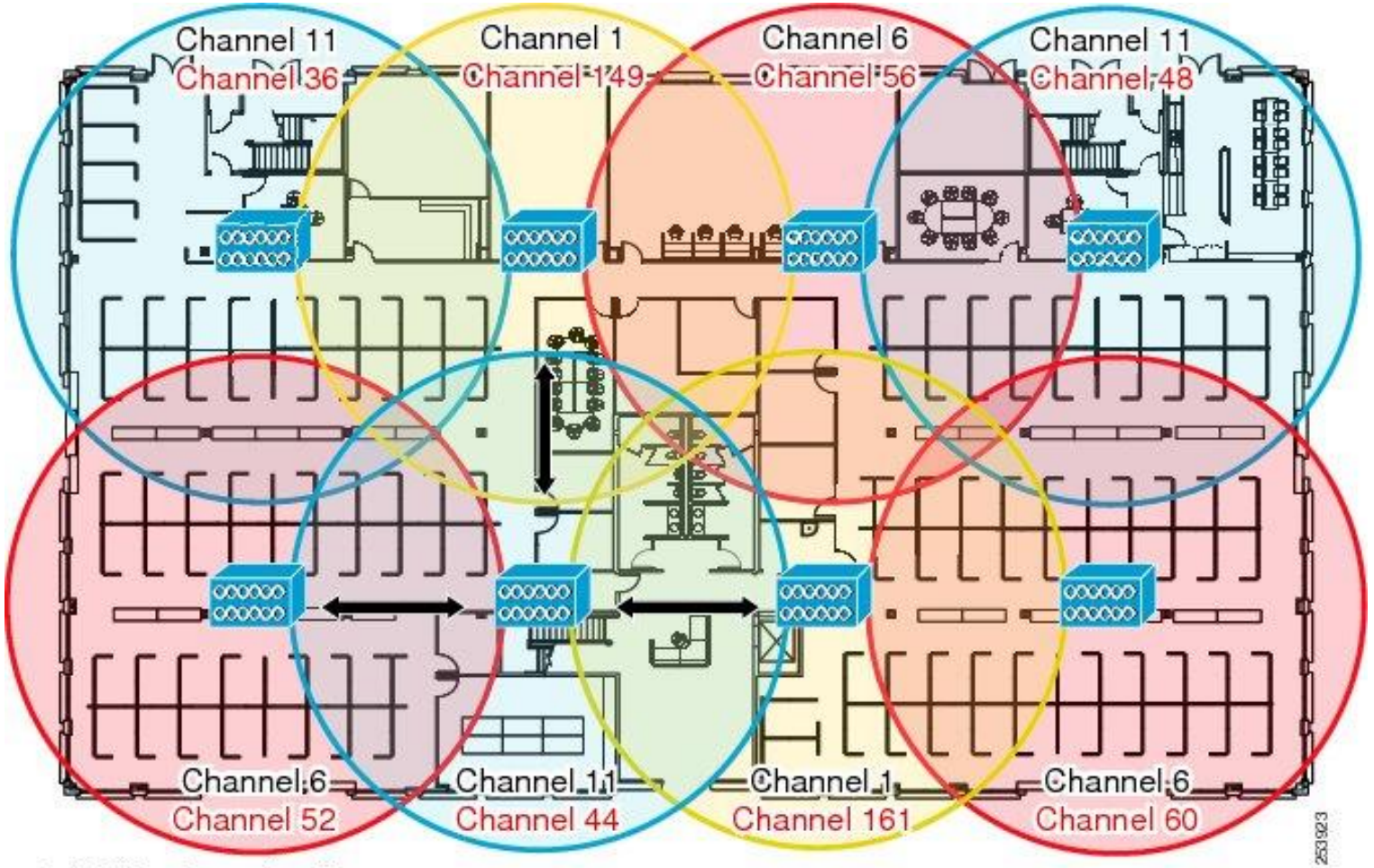
How many and how far apart?

Ideal scenario:

- Overlapping coverage
- Different channels



Optimum WAP Configuration



2.4 GHz channel cells
5 GHz channel cells

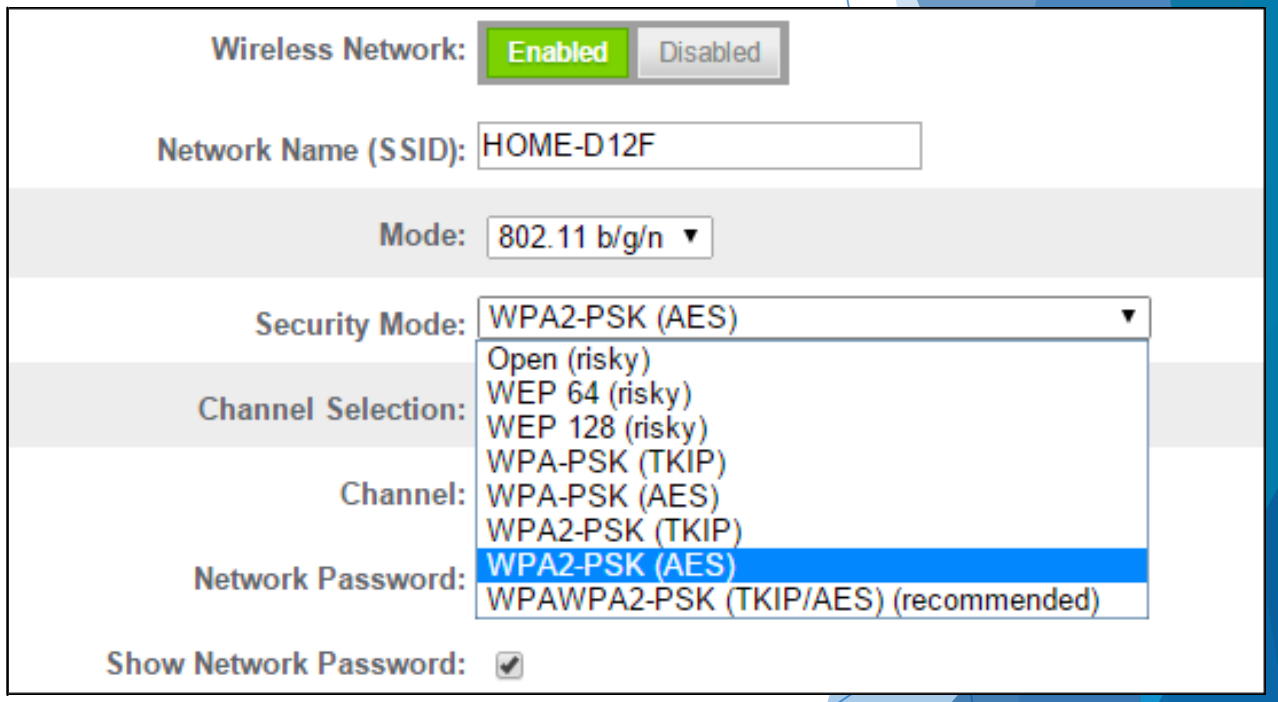
Minimum of 20% Overlap

Topics

- What is Wi-Fi?
- Networking basics
- Equipment
- Configurations
- **Security**
- Tools
- Troubleshooting

Wi-Fi Security Protocols

- Wi-Fi Security Protocols
  - WEP – Wired Equivalent Privacy
  - WPA – Wi-Fi Protected Access
  - WPA2 - Wi-Fi Protected Access II
- Wi-Fi Encryption Algorithms
  - TKIP – Old, now obsolete
  - AES – Introduced with WPA2



Open Portal

- Guest access without a SSID password
- Requires user to login, or accept terms for free access
- Commonly available on WAP configurations
- No control over who connects

MAC Level Access

- Restrict access to preselected physical devices
- Can be used to restrict non-authorized devices

- Every network device has a predefined MAC level address in the format:

MM:MM:MM:SS:SS:SS

Where the first half is the manufacturers ID (M) and the second half is a unique identifier for that device (S)

Other Security Considerations

Network Isolation: VLANs and Subnetting

What devices on your network do Wi-Fi connections have access to?

- Router
- File servers
- Printers & Copiers
- Thermostats, Heating and AC controls

What is the router (and WAP) administrative password?

- Still the default or easily guessed and hacked?

Is management login over Wi-Fi enabled?

Topics

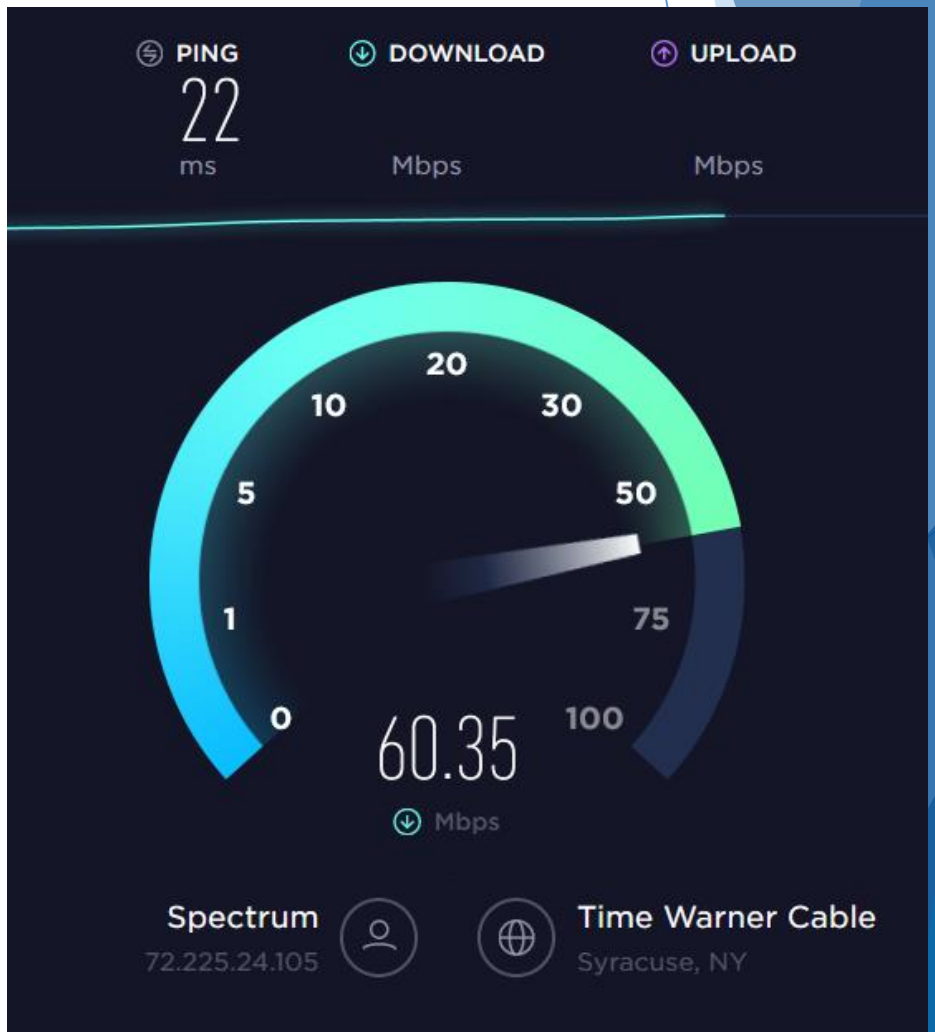
- What is Wi-Fi?
- Networking basics
- Equipment
- Configurations
- Security
- **Tools**
- Troubleshooting

Wi-Fi Tools

- Bandwidth test
- Android Wi-Fi Analyzer
- Windows Wi-Fi Analyzer
- Cable tester
- WAP connections
- Router status
  - DHCP status
  - Logs

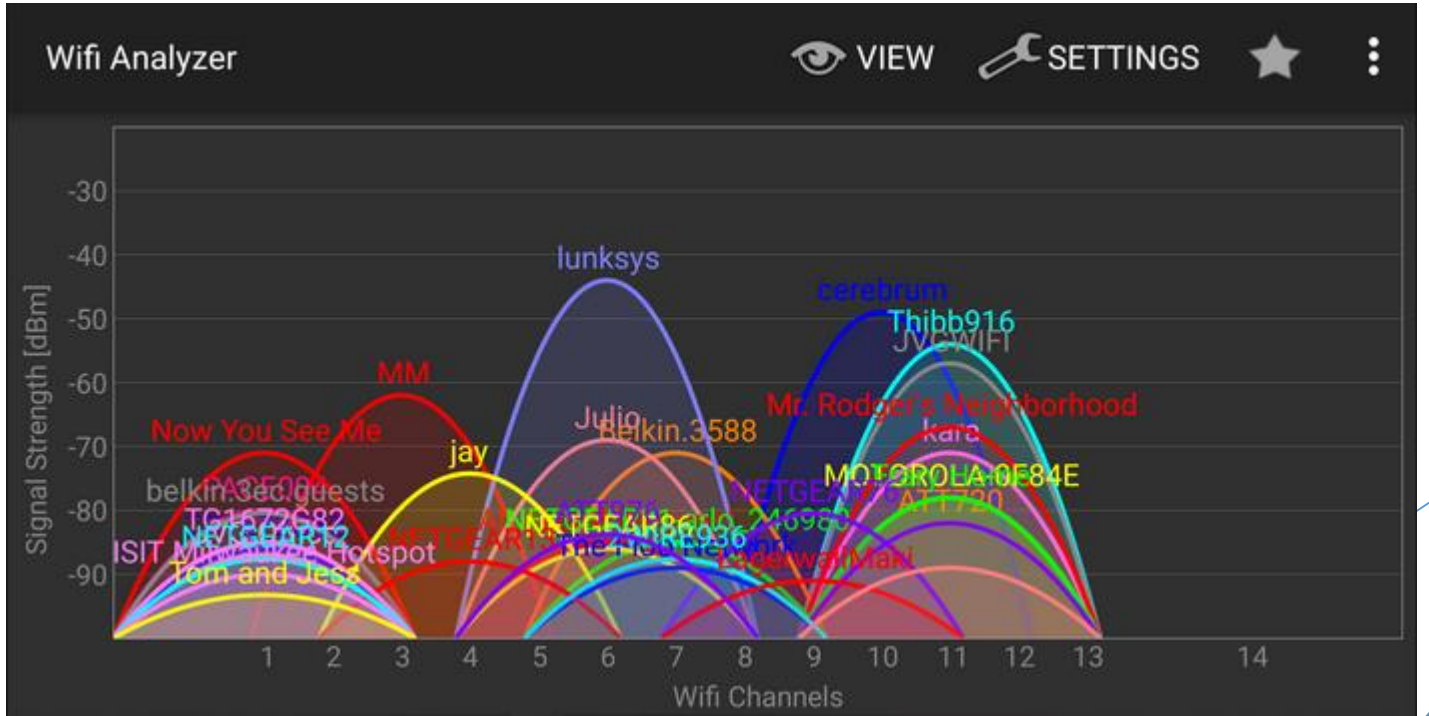
Bandwidth Test

- www.spectrum.com/internet/speed-test.html
- www.speedtest.net
- www.bandwidthplace.com

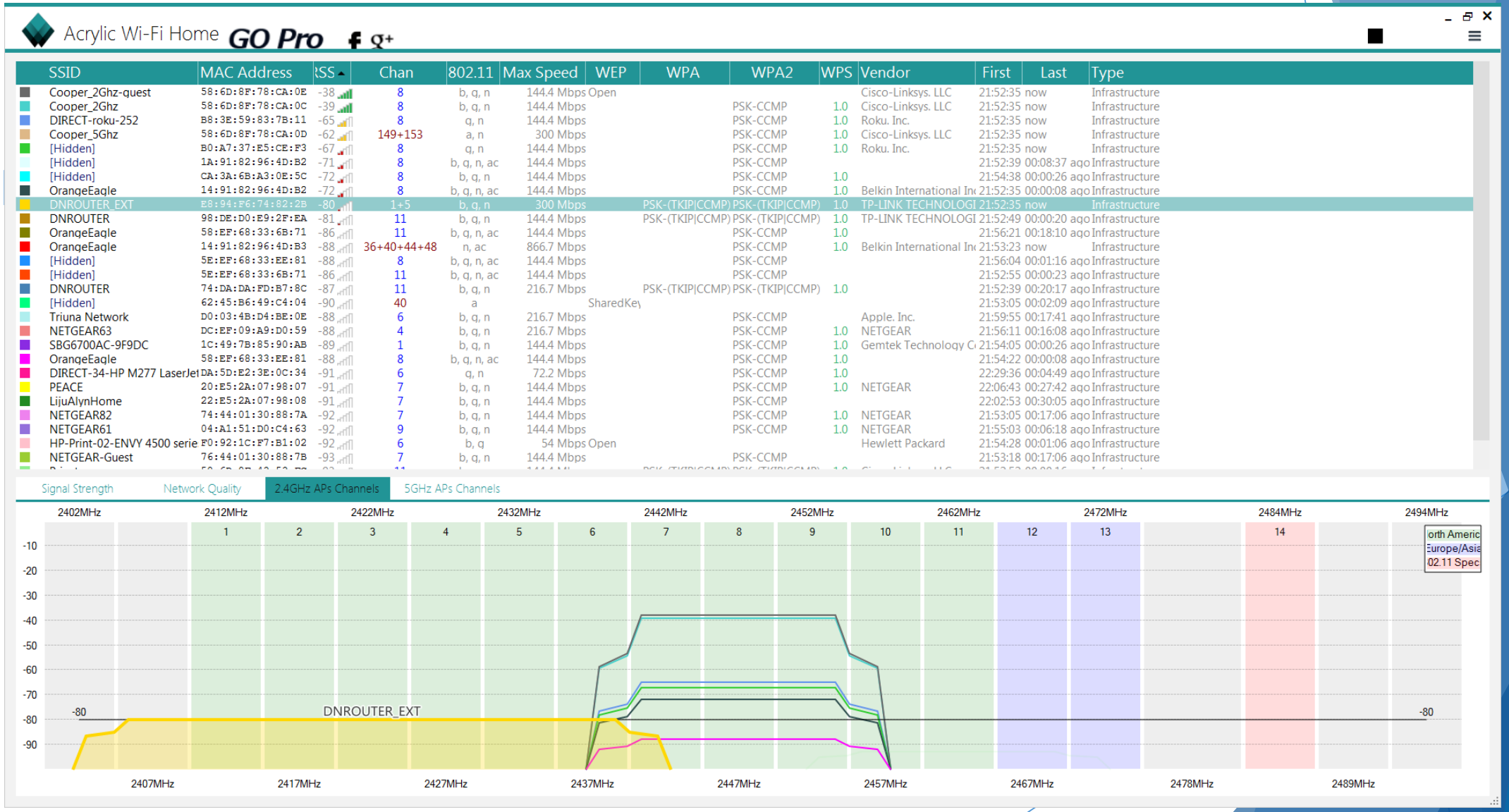


Android Wi-Fi Analyzers

- Netspot https://www.netspotapp.com Wi-Fi Analyzer http://wifianalyzer.mobi
- ScanFi https://play.google.com/store/apps/details?id=com.ScanFi
- Network Signal Info https://play.google.com/store/apps/details?id=de.android.telnet

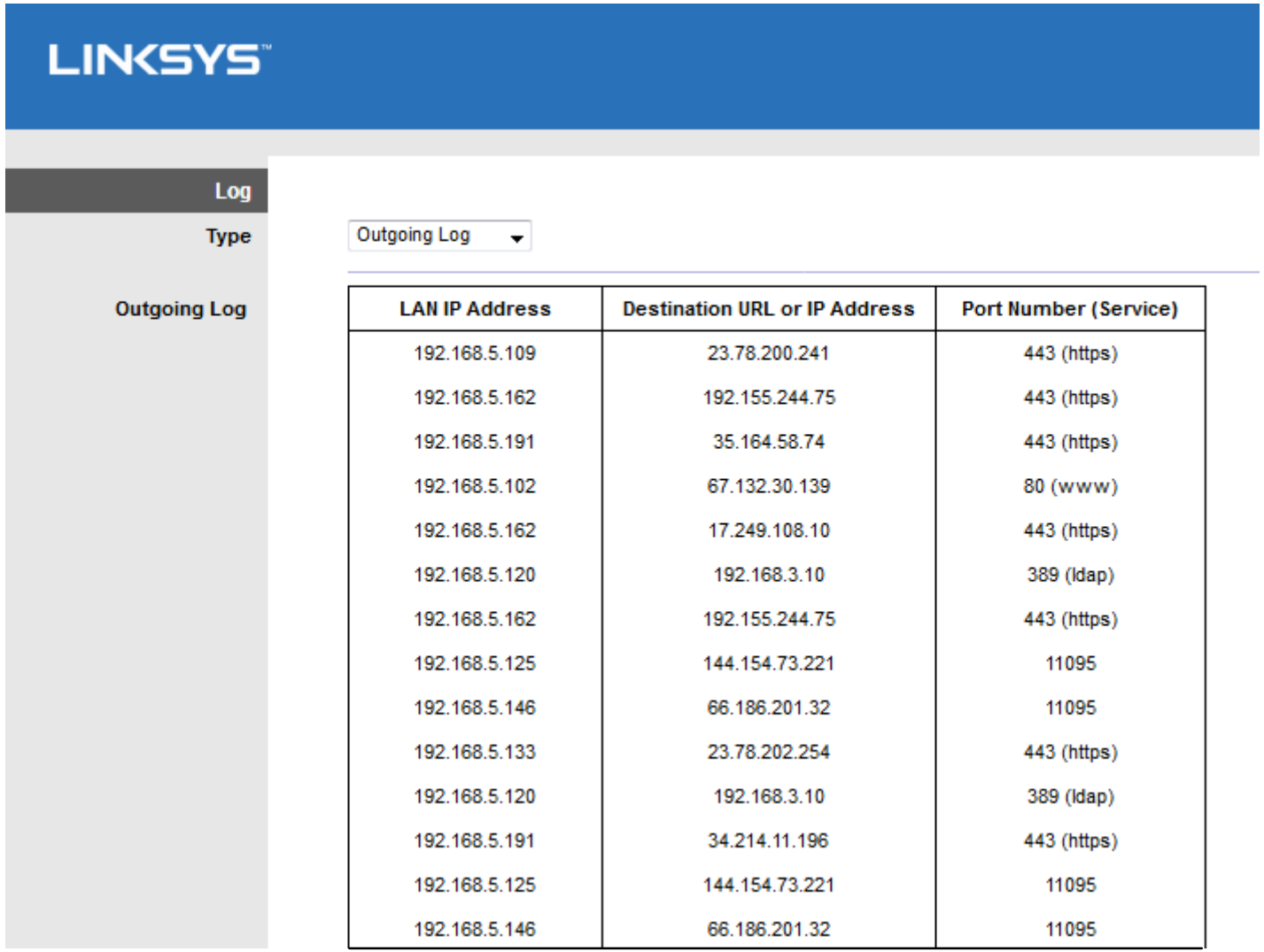


Acrylic Wi-Fi Home - www.acrylicwifi.com



Cable Tester

Router & WAP status and logs



LAN IP Address	Destination URL or IP Address	Port Number (Service)
192.168.5.109	23.78.200.241	443 (https)
192.168.5.162	192.155.244.75	443 (https)
192.168.5.191	35.164.58.74	443 (https)
192.168.5.102	67.132.30.139	80 (www)
192.168.5.162	17.249.108.10	443 (https)
192.168.5.120	192.168.3.10	389 (ldap)
192.168.5.162	192.155.244.75	443 (https)
192.168.5.125	144.154.73.221	11095
192.168.5.146	66.186.201.32	11095
192.168.5.133	23.78.202.254	443 (https)
192.168.5.120	192.168.3.10	389 (ldap)
192.168.5.191	34.214.11.196	443 (https)
192.168.5.125	144.154.73.221	11095
192.168.5.146	66.186.201.32	11095

Software Tools

- ping
- ipconfig

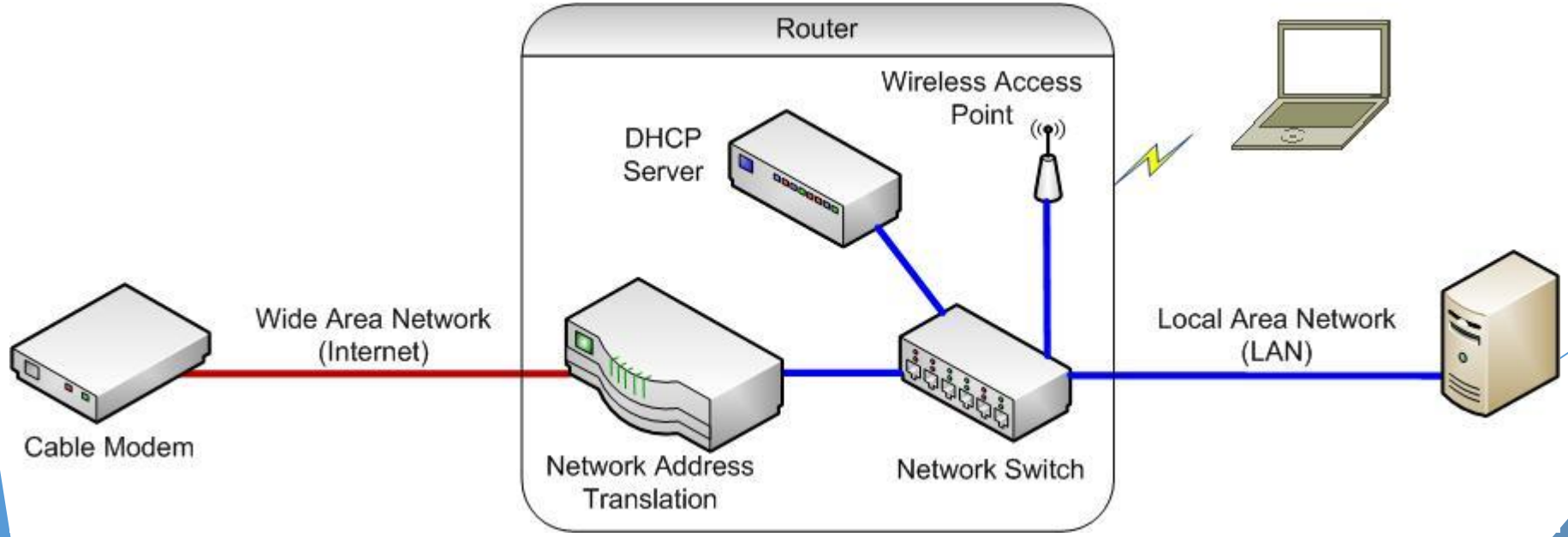
  (ifconfig on Linux)
- nslookup
- traceroute

Topics

- What is Wi-Fi?
- Networking basics
- Equipment
- Configurations
- Security
- Tools
- **Troubleshooting**

Connection Sequence

- Display available wireless networks (SSID)
- Connect to a wireless network with password
- Once connected, DHCP server provides
  Network address, subnet, gateway and DNS server
- DNS server looks up IP address of remote site to access
- Sends a request to the Internet through the gateway



Troubleshooting methods

Is it a Wi-Fi problem or network problem?

- Run bandwidth test
- Do you have an IP address, subnet, gateway and DNS?
- Do you have sufficient signal strength?

Common problems

- Low signal strength
  - Interference (microwave ovens, plasma TVs, etc. especially on 2.4 Ghz)
  - Distance from WAP
  - Blocked signal (plaster with chicken wire, ductwork, concrete, etc.)

- No connection
  - No IP address (?)
    - No IP addresses available to assign (?)
      (all address in the pool are in use)
      - Too many users, OR – is DHCP address lease time too long?

Vendors and Sources

Hardware

- B&H www.bhphotovideo.com
- NewEgg www.newegg.com
- CDW www.cdw.com

Software

- Tech Soup www.techsoup.org

Cables

- iofast www.iofast.com

Amplifiers, speaker and everything else!

- Monoprice www.monoprice.com

Thank You!